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COMPATIBILITY STANDARDS AND THE MARKET FOR TELECOMMUNICATIONS SERVICES

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1. INTRODUCTION

Not so long ago, the determination of technical standards in the United States telephone industry was primarily an internal matter for the American Telephone and Telegraph Company. To be sure, AT&T had to coordinate with foreign telecommunications entities, with independent telephone companies, and with the United States Department of Defense, but the degree of coordination was relatively minor and AT&T had substantial latititude in determining the standards that were employed. However, three forces have caused this situation to change dramatically.

First, because of the entry of large numbers of competing suppliers of equipment and services into the United States telecommunications industry, standard-setting has moved from the technical concern of a single firm to a factor with important implications for competition. As a result, the processes by which standards are set have come to be subject to detailed scrutiny by both the regulatory authorities and the courts. In a sense, telecommunications standards have become too important to leave their determination solely to the telephone companies.

Second, the divestiture of the Bell Operating Companies from AT&T, has, by fragmenting the telephone industry, reduced the ability of AT&T to determine standards as it had in the past. Horwitt (1986, p. 27.) notes that "the market has changed [drastically] since predivestiture days, when Ma Bell set telecommunications standards and other carriers and equipment vendors had no choice but to follow. Now, AT&T is just one more vendor--albeit a formidable one--lobbying for industrywide adoption of the technologies and protocols it wants to use." To an increasing degree, AT&T must accommodate to the choices made by others rather than dictate the standards to which others must conform.

Third, the growing internationalization of telecommunications technology and services has resulted in an increased role for international standard-setting bodies. As a result, the autonomy previously possessed by the United States to set standards has been reduced and the needed degree of coordination with suppliers in other countries has increased. According to Pool (1984, p. 119.), "Until now

in the telecommunications field there have generally been two sets of standards, the CCITT standards of the International Telecommunications Union followed in most of the world and the Bell System standards which prevailed in America (about half the world market). In the future...CCITT standards will become more influential in this country, and AT&T will have an incentive to reduce its deviations from them." The major effort presently underway at the International Consultative Committee for Telephone and Telegraph (CCITT) to establish standards for Integrated Services Digital Networks (ISDN), where the United States in only one of a large number of players, is an important indication of this change.

This paper analyzes the processes by which standards are produced in the telecommunications industry, focusing particularly on *voluntary* standards that are established cooperatively and *de facto* standards that are established by the "market." Section 2 considers the forces that determine which process will be used to determine a standard. Section 3 examines cooperative standard-setting in practice. It describes how voluntary standards are set both in the United States and internationally. Section 4 surveys the burgeoning economic literature on non-cooperative standard-setting, i.e., the determination of *de facto* standards. Section 5 considers the impact of standards on competition. Section 6 briefly surveys some recent attempts by the Federal Communications Commission to prevent standards from being used anticompetitively. Section 7 discusses two examples of the processes by which standards are being established in the telecommunications industry. Section 8 presents a brief conclusion.

2. THE DETERMINANTS OF THE STANDARD-SETTING PROCESS

There is no standard way in which standards are developed. In some cases, standards are *mandated* by government agencies using administrative processes. In others, *voluntary* standards are established cooperatively, with information being exchanged, technologies being altered, and/or side payments being made to achieve a consensus. Finally, standard-setting may be left to "the market," where *de facto* standards emerge noncooperatively.

Two factors that affect the nature and outcome of the standard-setting process are especially important. The first concerns the private incentives that each of the interested parties--developers, manufacturers, buyers--have to promote the universal adoption of any standard. Such incentives might be low because, even where all parties benefit from the existence of a standard, the private costs of participating in the process by which a standard is adopted may overwhelm the benefits of participating. This is especially likely to be the case for the establishment of systems of weights and measures and standards relating to the use of common terminologies.

The incentive to promote standards may also be low when standardization eliminates a competitive advantage and this swamps the benefits of having a standard. For example, Brock (1975) reports that IBM was unwilling to accept the COBOL-60 specifications for its business language because it wished to prevent the competition to which it would be exposed if there were a common business language. More recently, Horwitt (1987b) reports that American computer vendors such as IBM and telecommunications carriers such as Telenet are reluctant to adopt the CCITT X.400 electronic mail standard. Although adoption of the standard would permit communication between subscribers to different electronic mail systems, it would also permit subscribers to move easily from one vendor to another.[1]

At the opposite extreme are cases in which the expected gains to all parties from promoting the universal adoption of a standard exceed the costs they incur from doing so. For example, Hemenway (1975, pp. 13ff.) discusses how the early highly fragmented automobile industry was plagued by incompatibility problems. All manufacturers stood to gain greatly if standards were established and a high degree of participation was required if standardization was to be achieved. As a result, many incurred the the costs of participation.[2] With the later consolidation of the industry, the benefits of standardization have become less important.

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[1]By contrast, in Europe the strong demand for X.400 products has apparently forced U.S. vendors to support the standard in order to participate in the electronic mail market.

[2]If everyone benefits from having a standard, but the benefits are

The second factor affecting the way standards are set is the extent to which the interested parties have different views about which standard should be chosen. Differences in preferences are especially *unlikely* when there are no important differences among technologies, so that what is important is only that a standard be chosen, not what the standard is. Time keeping and the use of calendars may be examples where no individual cares which system is chosen so long as there is some generally accepted method.[3] Moreover, even when there are differences among technologies, so that the parties are not indifferent among them, the same technology may still be everyone's preferred standard.

On the other hand, agents frequently differ in the standards that they prefer. For example, manufacturers of VHS and Beta videocassette recorders would have different preferences as to which technology was adopted if standardization were attempted. Similarly, computer manufacturers who have designed their machines to work with specific operating systems would prefer different systems as the industry standard. Still another example is that some users of videotex prefer the North American Presentation Level Protocol Syntax (NAPLPS), with its sophisticated graphics capability, while other are content with the less expensive text-only ASCII standard. (Besen and Johnson, 1986, pp. 80-84.)[4]

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unequally distributed, those who obtain the largest benefits may be willing to incur the costs of setting standards while those with smaller benefits "free ride". This outcome, in which a public good is provided by those users who receive the largest benefits, has been referred to as "the exploitation of the great by the small." See Olson (1965) for a discussion of this issue. Olson discusses, among other examples, the case of international alliances in which large countries often pay a disproportionate share of the costs.

[3]The hour has not always been of fixed length. At one time, day and night were each defined to have twelve hours. As a result, the length of an hour fluctuated over the year. See Hemenway (1975, p. 5.). Similarly, many types of calendars have been used throughout history. See *Collier's Encyclopedia* (1979, Volume 5, pp. 136-145).

[4]In many cases, even if agents have no preferences when a technology is first introduced, they may develop preferences once they have adopted a particular technology. Thus, while it makes little difference in principle whether cars drive on the left- or right-hand side of the road, once a convention has been adopted, owners of

Where preferences differ, each party will promote as the standard the technology that maximizes its private benefits, not the one that maximizes total social benefits.[5] In these cases, standard-setting can no longer be viewed solely as a search for the technically best standard, or even as a process for establishing one of a number of "equivalent" technologies as the standard. Instead, standard-setting is a form of competition in which firms seek to gain advantages over their rivals.

We can now identify four cases that differ in whether the interest in promoting any universal standard is large or small and in whether preferences are similar or diverse. The case in which there is a large interest in promoting a universal standard and preferences are similar is what can be called the *Pure Coordination Case*. Here, either there are a number of possible standards among which everyone is indifferent, or the same technology is preferred by all, and the *per capita* rewards to participation in standard setting are large enough to induce everyone to participate. The standardization process is simply a matter of agreeing on which alternative to use. The agreement, once it is reached, is self-enforcing since no party has an incentive to deviate unilaterally. In the language of game theory, there are either multiple equilibria with identical payoffs or a unique equilibrium that is Pareto superior, i.e., everyone prefers it to any other. The standardization process serves to select an, or the, equilibrium.

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automobiles and operators of trams or buses will usually favor the status quo. When Sweden decided to switch from the left-to the right-hand side of the road in the late 1960's, a national referendum voted overwhelmingly against the change. (Kindleberger, 1983, p. 389). Similarly, owners of railroads with incompatible gauges will each have a preference for the gauge used by their rolling stock. In the case of railroads, another interested group was workers who where employed to change the settings of the wheels of the rolling stock as it passed from one gauge to another. Their interests were in opposing any standardization, since their jobs were at stake. (Nesmith, 1985). This suggests that instances in which agents are indifferent may be rare once there is a substantial installed based of equipment.

[5]This assumes that side payments are not possible.

Much standardization is very close to the Pure Coordination Case. While there may be some differences in preferences, these differences are small relative to the gains from achieving standardization. Here, standard setting is likely to be seen as an activity in which experts seek the best technical solution or, at least, choose a standard from a number that are equally good. In short, standard setting is a game in which everyone obtains a positive payoff and, moreover, it is one in which the choice that maximizes the payoff to any party maximizes the payoffs to all others. This view dominates descriptions of the standard-setting process that are produced by standard-setting organizations.

Even where preferences do not differ, however, standardization achieved through private voluntary agreement may not occur. The reason is that the gains to any party may be so small relative to the cost of participation in standard-setting that "free riding" on the part of everyone results in no standard at all. In what might be called the *Pure Public Goods Case*, the *per capita* gain from standardization is too small for anyone to find it worthwhile to participate in the process. Although everyone desires that standardization be achieved, and differences in preferences are small, no agent has a sufficiently large interest to develop the standard. This outcome is especially likely in industries that are highly fragmented, or where the beneficiary of standardization is the public at large. Here, if standardization is achieved it is likely to require government intervention, as in the establishment of standards for weights and measures, time, and language. Alternatively, several incompatible technologies may exist simultaneously.[6]

A third case involves large differences in preferences and little incentive to promote the adoption of a universal standard.[7] In the *Pure*

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[6]Paradoxically, where standardization cannot create a competitive advantage, so that achieving a consensus should be easy, the incentive to free ride is greatest.

[7]This does not mean that there are no benefits from standardization but only that the distribution of benefits is very sensitive to the standard that is chosen.

Private Goods Case, if there is no dominant firm, standardization cannot be expected to be achieved voluntarily. Here, private parties would not promote the creation of a formal standard-setting body and, if such a body were established, the objectives of participation would be to promote a favored candidate as the standard or to prevent the adoption of another. Unless side payments are possible, the most likely result is stalemate, with no party being willing to adopt the technology preferred by others. Participants in standards meetings may attempt to stall the proceedings by, for example, continually introducing new proposals and providing other participants insufficient time to analyze them. The outcome will be either simultaneous use of incompatible technologies, the selection of a *de facto* standard through the market, or the failure of the technology to develop because of the absence of a standard.

Although, in principle, government intervention can break a stalemate, such intervention may itself be the object of controversy, so that the government may be reluctant to intervene. The stalemate might also be broken if there is a dominant firm. However, if the dominant firm is opposed to universal standardization, it will be a *Reluctant Leader* and may attempt to prevent its rivals from producing compatible products.[8]

A firm with a large market share may be reluctant to promote its technology as an industry standard if it fears that the demand for the products of its rivals will increase at its expense if they can offer compatible products. For example, recently it was reported (Ryan, 1987) that Ashton-Tate has attempted to prevent the adoption of its Dbase language as an industry standard. The firm's chairman is quoted as stating that: "The Dbase standard belongs to Ashton-Tate and Ashton-Tate intends to vigorously protect it. It's proprietary technology." The argument is that Ashton-Tate's large market share makes it less concerned about the benefits of compatibility than are its rivals.

[8]See Braunstein and White (1985) for a discussion of allegedly anticompetitive standards practices in the computer, photography, and telecommunications industries.

Another possible example of reluctant leadership occurs where the dominant firm is dominant because it controls access to an input that its rivals need to market either complete systems or individual components. Under certain circumstances, such a firm may prefer that its rivals be unable to offer components that are compatible with its "essential" input. The argument that IBM attempted to make it difficult for competing manufacturers of peripheral equipment to offer products that were compatible with IBM's mainframes was an important element of the government's case in the 1969 Sherman Act antitrust suit against the company. A similar argument was made in the government's 1974 suit that led to the divesititure of the Bell Operating Companies from AT&T, where the essential input was access to the local distribution facilities of the operating companies.

In the fourth case, there are large differences in preferences and each of the interested parties has a large interest in promoting the universal adoption of a standard. In this *Conflict* case, a dominant firm may, if it desires, attempt to establish a *de facto* standard. Here, the dominant firm will be a *Cheerful Leader* and other firms may be forced to adopt the technology that it prefers. This is apparently what occurred in the emergence of the IBM personal computer as an industry standard.

In the absence of a dominant firm, the interested parties will all participate eagerly in the standardization process. The process can be expected to involve side payments and coalition formation. For example, Horwitt (1987a, p. 6) reports that a number of computer software and hardware vendors recently agreed "to surrender market dominance based on proprietary products in favor of a standardized, public-domain Unix environment....One major thrust behind the standards is vendors' realization that a fragmented Unix cannot effectively compete in the mid-range system against emerging proprietary products from the likes of Digital Equipment Corp. and IBM." The vendors were reported as "willing to cooperate with their competitors - or even adopt a competing product - in order to hasten commercial availability of the multivendor programming and networking products that their customers demand."

Similarly, all major European equipment manufacturers, together with Digital Equipment and Sperry, have formed the X/Open Group to promote a standardized version of the Unix operating system. Their objective is to permit the portability of applications software among computers made by different manufacturers in order to "preempt any attempt by IBM to establish de facto minicomputer standards, as it has for mainframes and personal computers." (Gallagher, 1986, p. 121.)

Firms can also be expected to promote their own products in the market during the standardization process in order to make more credible a threat to "go it alone." They may also attempt to employ the government to increase their leverage either in the market or in cooperative standard setting.[9] However, there will be considerable pressure for a standard to be adopted.

The above four-way classification of the standards process is summarized in Figure 1:[10]

As we have noted above, when standard-setting bodies describe their activities, they typically characterize them as involving Pure Coordination. In these descriptions, the participants are willing to expend considerable resources to achieve compatibility and any conflicts about what the standard should be reflect differences in technical judgments. Although standardization may not come easily in these cases, standard-setting bodies will generally be able to achieve the needed degree of coordination. At the same time, the conventional description of standard-setting fails to encompass a large and important number of

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[9]The case of AM stereo may be apposite. After the FCC decided not to adopt a standard but to leave leave standard-setting to "the market," some of the contenders succeeded in having the FCC revoke Harris' type-acceptance. This forced Harris temporarily to withdraw from competition and stations using its system to cease operating in stereo, an example of the use of governmental processes to gain a competitive advantage. Later, Harris dropped out of the competition and stations using its technology switched to using Motorola's, an example of coalition formation. See Besen and Johnson (1986) for a fuller account.

[10]Note that all firms in an industry may not be in the same cell. The examples of dBase and Unix discussed above are apparently cases in which the dominant firm prefers that no standard be adopted, because it thereby retains a competitive advantage, and smaller firms prefer that a standard be chosen, because that enhances their ability to compete.

CONFLICT (VHS vs. Beta)	PRIVATE GOODS (Ashton-Tate)	HIGH	VESTED INTEREST IN A PARTICULAR STANDARD
COORDINATION (Early Automobiles)	PUBLIC GOODS (Time)	LOW	
HIGH	LOW		

INTEREST IN PROMOTING THE UNIVERSAL ADOPTION
OF ANY STANDARD

Fig. 1--The determinants of the nature of the standards process
(Examples in parentheses)

cases in which differences about what the industry standard should be are not primarily technical -- the Conflict case -- or where some of the parties actually prefer incompatibility -- the Private Goods case. Much of the remainder of the paper examines situations in which the interests of the parties are not necessarily congruent because they raise the most interesting and difficult standardization issues from the point of view of public policy. However, we do not mean to suggest that the Pure Coordination Case is unimportant and, indeed, we provide a detailed analysis of the possible role for cooperative standard-setting in this Case.

Whether consensus will be achieved in private cooperative standard-setting depends on a number of factors including: (a) the importance of the benefits of standardization, (b) whether a small number of participants can prevent an effective standard from emerging;[11] (c) the extent to which the interests of the participants diverge; and (d) whether side payments are possible.

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[11]This can arise either where all participants want a standard but differ strongly as to what that standard should be, or where some participants do not want any standard to emerge at all. In the latter case, those firms that do not want a standard will not participate in the process, as apparently occurred in the case of the COBOL and dBase standards noted above.

The prospect of achieving consensus is greater the greater are the benefits from the network externalities that standardization produces. At one extreme, if consumers are reluctant to purchase a good from any vendor because they fear that they may be "stranded" with the wrong technology, all vendors have a strong interest in agreeing on a standard. In such cases, firms may be willing to agree to conform to a standard that is not the one they prefer if the alternative is to have no sales at all. On the other hand, the greater the ability of a firm to have sales even where there are no compatible products, the more reluctant it will be to conform to a standard other than the one it prefers.

If the success of a standard depends on obtaining agreement from all participants, standardization is less likely than where a smaller majority is required. Where unanimity is required, any participant can hold out, refusing to support a standard unless he obtains a large share of the resulting benefits. This can involve either insistence that his preferred technology be chosen as the standard or a demand for payment in some other form. Since all participants can behave in this manner, consensus is unlikely. This may explain why standard-setting bodies typically require less than unanimous consent for a standard to be adopted.[12]

Clearly, the more divergent are the interests of the participants, the less likely it is that a consensus will emerge. Where preferences are similar, the process of standardization involves only learning that this is the case.[13] Once everyone knows that everyone else prefers the same technology, each can proceed to adopt the technology in complete

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[12]Where less than unanimity is required, a small number of firms may agree to support a standard, leaving to others the decision as to whether to conform. Recently, a number of computer and hardware manufacturers, not including IBM, discussed the creation of a standard for extending the bus for the IBM PC AT from 16 to 32 bits. See "Inside the IBM PCs, Editorial, *Byte*, 1986 Extra Edition, pp. 6, 8. Section 3 discusses the rules relating to the adoption of voluntary standards by committees.

[13]See Farrell and Saloner (1985), discussed below, for an analysis of the role of information in standard-setting.

confidence that his behavior will be emulated. Here, information sharing can promote the adoption of a standard that otherwise would not emerge. By contrast, where preferences diverge, not only will such confidence be lacking but each participant will tend to exaggerate the differences in order to have his technology chosen. Thus, each participant may contend that he will not follow the lead of another even if, in fact, he would. The result is to reduce the likelihood that anyone will attempt to start a "bandwagon."

Finally, the ability to make side payments may overcome what otherwise would be resistance to agreement on a standard. Especially where the difficulty in reaching agreement results from large divergences in preferences, if those who gain most from the standard that is adopted share those gains with others, the reluctance to conform may be overcome. The sharing of gains need not involve cash transfers but could, for example, require that the "winners" license their technologies on favorable terms to the "losers."[14]

3. COOPERATIVE STANDARD-SETTING IN PRACTICE

The analysis in the previous section suggests that there are a wide variety of circumstances in which cooperative standard setting is viable and productive. In fact, an important response to the need for coordination of product design has been the evolution of a strikingly large and complex standard-setting community charged with the responsibility and authority to negotiate and adopt standards for their industries. In addition, liaisons and affiliations among standard-setting bodies have been formed across industry and national boundaries as the need has arisen. The result is a standards community comprising hundreds of committees and involving over a hundred thousand individuals. It is particularly remarkable that, for the most part, this community has emerged at the initiative of industry participants and without governmental intervention or direction. Indeed,

[14]An alternative is the adoption of "compromise standards" that borrow aspects of the technologies that the different participants prefer in a way that leaves none with an advantage. One reason that this approach may be used is that arranging for side payments is often difficult.

governmental agencies often take their guidance from the industry bodies and formally adopt as mandatory standards the voluntary standards that these bodies produce.

a. Voluntary Standard-Setting

At some stage, usually fairly early in the development of a new product, manufacturers and purchasers often realize that economies can be reaped by adopting voluntarty standards for some of the product's components or features. Using a subcommittee of an existing trade association or standard-setting organization, comments are obtained from all interested parties through a lengthy and formal procedure.[15]

Acceptable standards emerge under "the consensus principle" which generally connotes "the largest possible agreement...among all interests concerned with the use of standards." (Verman, 1973, p. 12).[16]

A central clearinghouse is used to keep track of, and disseminate information about, standards. In the U.S., this function is provided by the American National Standards Institute (ANSI), a private organization with more than 220 trade associations, professional and technical societies, and more than 1000 corporations as members (National Bureau of Standards, 1984).[17] ANSI approves a standard when it finds that its criteria for due process have been met and that a consensus among the interested parties exists. Some 8500 American National Standards have been approved in this manner (NBS, 1984, p. 71).

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[15] See Sullivan (1983) for more details about this process.

[16] The consensus principle is explicitly not taken to imply unanimity (Sanders, 1972). Certainly it does not imply a simple unweighted majority of industry participants. Hemenway (1975, p. 89.) notes, for example, that "a number of negative votes of groups that are only distantly concerned with the subject matter may be discounted in the face of the affirmative votes of parties that are vitally affected by the standard".

[17] Originally organized in 1918 as the American Engineering Standards Committee, comprising four engineering societies, mining, civil, chemical, and mechanical, its name was changed to the American Standards Association in 1928. At that time, its membership was opened to trade associations and government bureaus. Finally, from 1966-69 it was reorganized under the name of ANSI and the focus of its role shifted from standards creation to a broader coordinating role. See Sullivan (1983, p. 33) and Hemenway (1975, p. 88) for additional detail.

In the United States, the decisions of standard-setting bodies, and their operating procedures, have been subject to antitrust scrutiny. At least three organizations have been held to have violated the antitrust laws when they refused to certify that a new technology conformed to an industry standard.[18] As a result, the principle has been established that antitrust liability may be incurred by private voluntary standard-setting organizations if their actions are anticompetitive,[19] and these organizations must now expect that their activities may be subject to challenge. Indeed, in one situation of which we are aware, a trade association actually declined to adopt an industry standard because it feared that it could avoid antitrust liability only by adopting costly procedures to assure that its actions would be perceived as "fair."[20]

The need for standards transcends national boundaries. The same forces that produced the formation of national standards bodies have also led to the creation of organizations for international standardization. In 1946, delegates from 64 countries established the International Standards Organization (ISO).[21] In 1947, the International

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[18]See American Society of Mechanical Engineers, Inc., v. Hydrolevel Corporation, 456 U.S. 556 (1982), Radiant Burners, Inc. v. People's Gas Light & Coke Co., 364 U.S. 656 (1961), and Indian Head, Inc. v. Allied Tube & Conduit Corporation, United States Court of Appeals for the Second Circuit, 1987, slip opinion. See also Federal Trade Commission (1983) for an extended analysis of the potential for anticompetitive behavior in the development of standards.

[19]However, collective activity to influence *government* standard-setting is generally immune from liability under the antitrust laws. The Noerr-Pennington Doctrine adopted by the courts provides substantial antitrust immunity to firms acting collectively to influence legislative or regulatory behavior. See Fischel (1977) and Hurwitz (1985) for useful discussions of the Doctrine.

[20]See the discussion of the behavior of the National Association of Broadcasters in deciding whether to adopt an AM stereo standard in Besen and Johnson (1986).

[21]The ISO was preceded by the International Federation of the National Standards Association (ISA), formed in 1926 by about 20 of the world's leading national standards associations. The ISA disbanded in 1942 because of the war. (Sanders, 1972, p. 64.) In 1981 the ISO changed its name to "International Organization for Standardization" but retained the abbreviation ISO (Rutkowski, 1985, p. 20).

Electrotechnical Commission (IEC), formed some 43 years earlier, became affiliated with the ISO as its electrical division, considerably expanding its scope. There are two striking features of the ISO: its extent and the rate of growth of its output. Of the roughly 7500 international standards that had been written by early 1985, some 5000 had been developed, promulgated, or coordinated by the ISO (Lohse, 1985). This contrasts with the mere 37 ISO Recommendations that had been approved by the ISO's tenth anniversary in 1957, and the 2000 standards that had been written by 1972 (Sanders, 1972, p. 68).

As is the case with ANSI, the ISO is a nongovernmental, voluntary institution. It has 72 "full members" and 17 "correspondent members". The full members are national standards associations, such as ANSI, which have voting rights on the technical committees of the ISO as well as the Council and General Assembly.[22] The correspondent members are governmental institutions from countries that do not have national standards bodies. The writing of the standards is carried out by the 164 technical committees and their subcommittees and working groups of which there are about 2000 (Lohse, 1985). It is estimated that the number of individual participants has grown from some 50,000 in 1972 (Sanders, 1972, p. 68) to over 100,000 today (Lohse, 1985, p. 20). Some 400 international organizations, including the CCITT, which will be discussed below, have formal liaison with the ISO.

The same process for achieving consensus that characterizes national standard setting is present in the international arena.[23] Although the consensus principle is held as an ideal for the standards process at the international level as well (Sanders, 1972, p.12), formally a Draft International Standard (DIS) must be approved by 75% of the full members who have elected to participate in the relevant technical committee. "Two or more negative votes receive special

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[22]The ISO accepts as a member the national body that is "most representative of standardization in its country". Most of these (more than 70%) are governmental institutions or organizations incorporated by public law. (Rutkowski, 1985, p. 21).

[23]See Lohse (1985) and Sanders (1972) for more detail on the functioning of the ISO.

consideration" (Lohse, 1985, p.22). Once a DIS has been approved by a technical committee it must be adopted by the Council of the ISO as an International Standard.

It is significant that the number of ANSI standards exceeds the number of international standards. Because international standardization is a fairly new phenomenon, standardization is often achieved at the national level before it is taken up internationally. Indeed, in its early years, the ISO was mainly involved with coordinating existing national standards.

b. Standard-Setting in the Telecommunications and Computer Industries

Telephone services have traditionally been provided by Government-run (or, in the U.S., Government-regulated) monopolies. In Europe these are the PTTs (Post, Telephone and Telegraph Aministrations), while in the U.S., until recently, this position was held by AT&T. So long as these organizations had complete control over the design and use of the network, standardization within countries involved only a single firm. However, international standardization, requiring coordination among many firms, involved consultation and agreement among national Governments. It is not surprising, therefore, that there is a treaty-based organization to deal with standardization issues.

The International Telegraphic Union was formed by an agreement of 20 countries in 1865. In 1932, it merged with the organization created by the International Radiotelegraph Convention and was renamed the International Telecommunication Union (ITU).[24] The main goal of the ITU, which currently has 162 members, is to promote cooperation and development in telecommunications. The branches of the ITU most concerned with issues of standardization are the International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR). The latter is concerned with matters specifically related to radio propagation and facilities, while the former deals with all other telecommunications issues.

[24] See Bellchambers *et al* (1984) for details of the history of the ITU.

The results of CCITT and CCIR deliberations are usually adopted as *recommendations*. While these are not legally binding, countries find it in their interests to adhere to them in order to facilitate interworking of national systems. Although rarely done, the ITU can adopt CCIR and CCITT recommendations as treaty agreements (known as *regulations*). While these have been restricted mainly to issues relating to radio, the 1988 World Administrative Telegraph and Telephone Conference will consider regulations affecting "all existing and forseen new telecommunications services".[25]

Since the CCITT is a part of a a treaty organization, the U.S. is represented there by a delegation from the Department of State. Two public advisory committees, the United States Organization for the International Telegraph and Telecommunications Consultative Committee (USCCITT) and the United States Organization for the International Radio Consultative Committee (USCCIR), provide advice to the State Department on matters of policy and positions in preparation for meetings of the CCITT (Cerni, 1985).[26] The State Department is also able to provide accreditation to organizations and companies that allows them to participate directly in CCITT and CCIR activities. Historically U.S. representation has been made in this way through companies involved in the provision of telegraph and telcommunications services (Rutkowski, 1985, p. 25).

Several domestic voluntary standards organizations are also involved in the telecommunications standardization process. One of the most important of these is Committee T1 sponsored by the Exchange Carriers Standards Association (ECSA), which was organized after the divestiture of the Bell Operating Companies from AT&T to deal with standardization issues previously handled internally by AT&T.[27] This

[25] Resolution No. 10 of the Plenipotentiary Conference of the ITU (Nairobi, 1982), cited in Rutkowski (1985, p. 261).

[26] "Membership [in the USCCITT] is extended to all parties interested in telecommunications standards, including users, providers, manufacturers, national standards organizations, and Government Agencies". (Cerni, 1985, p. 38).

[27] See Rutkowski (1985) for details of ESCA and other voluntary standards organizations and Lifschus (1985) for a description of the activities of Committee T1.

committee, whose members include exchange carriers, interexchange carriers, and manufacturers, develops interface standards for U.S. networks. Although the private sector plays a large role in the development of U.S. telecommunications standards, it does so subject to the substantial authority of the Federal Communications Commission (FCC) to regulate domestic and international communications under the Communications Act of 1934.[28]

Standardization decisions lie at the core of the establishment of telecommunications networks.[29] The same is not true of computer hardware technology. Especially in the days when the mainframe reigned supreme, the major uses of computers were as stand-alone processors. Standardization issues revolved mainly around the ability of manufacturers of peripheral equipment to connect their products to the Central Processing Units of other manufacturers. Since there were only a few mainframe manufacturers, and they provided integrated systems, and thus were not dependent upon the equipment of peripheral manufacturers, they had little incentive to ensure that interfaces were standardized.[30]

Several factors have combined to increase the desirability of inter-computer communication. These include: the desire to make corporate and external data available to a wide range of company employees; the need to share information generated in a decentralized way resulting from the emergence and rapid acceptance of the microcomputer; and the increased use of computer technology in the service economy (e.g., banking, airline and theater reservations) and the desire to access these and other potential services (e.g., education, library access, grocery ordering, and mail) from the home.

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[28]Title I provides the FCC with general jurisdiction over communications services, Title II with specific jurisdiction over common carrier telecommunications services, and Title III with jurisdiction over the use of Radio Stations.

[29]This is not to say that they are essential, since often translators can substitute for interface standards. However, whether standards or translators are used, the issue of whether or how to standardize naturally arises.

[30]Users of computer languages, on the other hand, had obvious incentives to achieve standardization and utilized the typical voluntary committee structure.

The first important successes in standardizing data communications were not achieved until the mid-1970's. One of the most important early standards was CCITT Recommendation X.25, which established interface specifications between data terminal equipment and public data networks.[31] These early standards were imperative for meeting immediate requirements - they were not components of a grand design that would ensure compatibility of different protocols and system architectures (Folts, 1982).

The initiative for developing an overarching framework for information transfer between any two end-systems was taken by the ISO. The ISO initiative is generally perceived as a bold and farsighted attempt to avoid the haphazard evolution of incompatible protocols. In contrast to many standards proceedings, this initiative anticipated future needs rather than merely reacting to them.

The result of this initiative was the Open Systems Interconnection (OSI) reference model. This model provides a framework for structuring communication between separate end-users. The term "open" conveys the ability of any end-user to connect *with any other*. The forum in which such communication takes place is called the "OSI environment". An "end-user" is best thought of as a particular applications process (Folts, 1982). Thus, for example, an end-user could be a person operating a manual keyboard terminal, or a production-line control program.

The communication between application processes requires that a number of functions be performed. The OSI Reference Model structures these functions into seven layers.[32] Broadly speaking, the upper three layers provide support for the particular application being used. They provide the services that allow the application process to access the

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[31]These protocols are essential for packet-switched networks. In such a network, data to be transmitted from one user to another are arranged in "packets". In addition to the data, each packet includes such information as the users' addresses. Protocols establish, *inter alia*, call origination and acceptance formats, error checking, speed and flow parameters. See Rybcynski (1980) for the details of X.25.

[32]See Folts (1982) or Tannenbaum (1981) for a more detailed description of OSI.

Open System and to interpret the information being transferred to the application process. The lower three layers are concerned with the transmission of the data itself from one applications process to another. The middle layer (the "transport" layer) links the application process support layers to the information transmission layers.

Contemporaneous with the blossoming of opportunities from inter-computer communication has been a major change in the technology of telecommunications networks. Voice communication requires both a transmission and a switching technology. The transmission technology carries the voice signal through the network, while the switching technology is responsible for its routing. The traditional analog technology amplifies the voice signal in such a way that it can be transmitted. Each time the signal is switched, the signal must be interpreted and then transformed again and this process results in the accumulation of "noise."

The alternative digital technology immediately creates a digital representation of the voice signal. This digitized signal can then be switched repeatedly without decoding and redigitizing. Since the signals are in digital form, the switching is performed by computer. As the cost of computer technology has fallen, so has the cost of the digital technology. Accordingly, telecommunications networks are rapidly being transformed from analog to digital transmission and switching. Eventually, the entire telecommunications network will be digital, forming an Integrated Digital Network (IDN).

Once the telecommunications network transmits digital information, this network itself can be used for the kind of inter-computer communication discussed above. This vision of a single network that will be used for voice, data, facsimile, and video transmission is referred to as the Integrated Services Digital Network (ISDN). Because of the obvious connection between the work of the ISO on OSI and the interests of the CCITT in telecommunications, these two bodies are working together closely in developing standards for ISDN.[33]

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[33]Technical Committee 97, headquartered at ANSI in New York, is the ISO subcommittee responsible for ISDN standards (Rutkowski, 1985, p. 17).

4. NONCOOPERATIVE STANDARD-SETTING

An alternative to setting voluntary standards through committees is for standards to evolve through the adoption decisions of market participants. In order to evaluate the utility of the committee system, or the desirability of imposing mandatory standards, it is therefore necessary to understand how well "the market" would do in setting *de facto* standards.

There are several dimensions along which the market's performance should be evaluated. These include whether the market selects the appropriate standard; whether inferior standards are abandoned when new, superior, technologies become available; whether the appropriate trade-off between variety and standardization is made; and whether converter technologies are appropriately developed. These important economic issues were virtually ignored by economists until quite recently. A burgeoning theoretical literature is attempting to correct this failing. This section briefly reviews this literature.

The distinctive feature of the models discussed here is that the standardization create a *demand-side economy* of scale. In particular, where there are benefits to compatibility, users of a particular technology reap benefits when others adopt the same technology. Thus one individual's adoption decision confers a positive externality on other adopters. Since individual decisionmakers ignore these externalities in making their decisions, one cannot generally expect the outcomes to be efficient. Indeed, as we shall see, inefficiencies of various kinds can arise.[34]

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[34]Two other issues about the effect of standardization on market structure and firm behavior are also important. The first is whether, in the presence of benefits from compatibility, firms can take strategic actions to disadvantage their rivals. When an individual firm has the ownership rights to a given technology (such a firm is often called a "sponsor" of the technology in this literature), the adoption of the technology as a standard will confer some monopoly power. Thus each firm may be expected to take measures to encourage the adoption of its technology as the standard, and to protect and extend its monopoly power once it has been achieved.

The second issue is of particular importance in such markets as telecommunications, where customers use a primary product (e.g., the

a. Inertia and Momentum in the Adoption of a New Standard

The benefits from standardization may make users of a standardized technology reluctant to switch to a new, and perhaps better, technology, out of fear that others, bound together by the benefits of compatibility, will not abandon the old standard. If this is the case, it may be difficult for a new standard to be adopted. As a result, *de facto* standardization may retard innovation.

The first theoretical model of this phenomenon is due to Rohlfs (1974) who considers what happens when a given number of agents are simultaneously considering adopting a new technology.[35] Suppose that all potential adopters would adopt if each knew that the others would do so as well. However, no individual would adopt if he thought that he would be the only adopter. Rohlfs points out that there are generally multiple equilibria in this situation. One is for everyone to adopt the new technology while another is for no one to adopt it. Similarly, if some subsets of users are in favor of adoption but others are not, still other equilibria are possible.

Consider four potential adopters. Suppose that 1 and 2 will adopt if the other does but that 3 and 4 will adopt only if the other does and 1 and 2 also adopt. Even if all four agents are better off adopting, it is conceivable that inertia will lead to an equilibrium in which only 1 and 2 adopt, if that outcome is somehow "focal".[36]

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telephone network) in conjunction with secondary services (e.g., customer premises equipment and enhanced telecommunications services). In such markets the question arises whether firms with a dominant position in the primary market can employ control of interface standards to profitably extend their dominance to the secondary market. These two issues are discussed in Section 5.

[35]The model is actually cast in terms of agents choosing whether or not to join a telecommunications network, but the analogy to the choice of a standard is complete.

[36]How 1 and 2 manage to coordinate their behavior is, of course, important. The point of the example, however, is that 3 and 4 may be unsuccessful in achieving coordination even if 1 and 2 can do so. Note that this is an example of Pure Coordination if all four agents are better off adopting. If this is the case, a standard-setting body would succeed in promoting adoption of the new technology.

A second problem is that it may not be an equilibrium for all four to adopt and yet that may be the most socially desirable outcome. This occurs, for example, when 3 and 4 are moderately reluctant to adopt the technology but their adoption would make 1 and 2 much better off. Since 3 and 4 ignore the benefits that they confer on 1 and 2 in making their adoption decision, too little adoption may occur.[37] Indeed, 1 and 2 may not adopt the new technology if they are unsure that 3 and 4 will do so.[38]

Farrell and Saloner (1985) demonstrate that some of these potential inertia problems disappear if we allow for sequential rather than simultaneous decision-making and complete information. In that setting, they show that where all agents prefer joint adoption of the new technology to the *status quo*, adoption is the unique equilibrium.[39] Moreover, if the agents do not all prefer joint adoption of the new technology, the only equilibrium involves the largest set of possible adopters. Of those that do not adopt, there is no subset that desires to switch. This result suggests that the intuition about the possible innovation-retarding effects of standardization does not extend to a model where the timing of the adoption decision is endogenous and information is complete.

However, while this model provides a useful benchmark, it suffers from a lack of realism along a number of dimensions. First, the

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[37]Dybvig and Spatt (1983) demonstrate that, in some cases, simple subsidy schemes may alleviate both problems.

[38]Note that this is an example of Conflict and cannot be resolved by replacing non-cooperative standard-setting with a standard-setting body. Agents 3 and 4 will not switch even if 1 and 2 agree to do so.

[39]The proof uses the following backwards induction argument. Suppose that there are N potential adopters and N-1 have already adopted the technology. In that case, the Nth adopter will as well. Therefore, consider the N-1th adopter when N-2 have already adopted. That potential adopter knows that if he adopts that the final adopter will also, and so he, too, adopts. The same logic can be applied all the way back to the first adopter. This explains why a standard-setting body can succeed in achieving universal adoption only in the first of the two examples discussed above.

assumption that all potential adopters are perfectly informed about each others' preferences is not innocuous. Second, the model has a timeless quality to it. There are no transient costs of incompatibility, nor is adoption time-consuming. Finally, all potential adopters of the technology are extant at the time the adoption is first contemplated. In reality, some potential adopters will make their decision only some time in the distant future.

Richer models have been developed to incorporate each of these features. The conclusion that emerges uniformly from these studies is that the outcome of the adoption process may be inefficient. However, the inefficiency is not only that a socially efficient standard may not be adopted. It is also possible that a new standard may be adopted too readily, i.e., it may be adopted when, from a social point of view, it should not be.

For example, Farrell and Saloner (1985) consider what happens when two potential adopters are imperfectly informed about each other's preferences. They find that the outcome resembles a "bandwagon": if one potential adopter is very keen on the adoption of the new technology it will adopt early in the hope of inducing the other to follow. If a potential adopter is only moderately keen, it will employ a "wait-and-see" strategy, adopting only if the other is more eager and gets the bandwagon rolling.

"Wait-and-see" behavior can have the effect of stalling the bandwagon even when both potential adopters hope that adoption will occur. Thus, there may be too little standardization.[40] However, the converse is also possible. Suppose that two firms are currently both using an existing technology when a new technology becomes available and that only one firm favors switching to the new technology. That firm may adopt the new technology leaving the other with the choice of being the lone user of the old technology or switching as well. If the benefits to compatibility are large, the latter may find switching to be its best alternative. However, the firm that opposes the switch may be hurt more than the firm that favors the switch benefits, so that firms

[40] Postrel (n.d.) has extended the Farrell and Saloner (1986) results to the N-agent case.

in the aggregate are worse off than if they had remained with the old technology.[41]

Not only has it been shown that incomplete information can lead either to "excess inertia" or "excess momentum" in the adoption of a new technology, but Farrell and Saloner (1986b) provide two models in which this can occur even with complete information. The first model examines the case where only new adopters consider a new technology but the installed base of users of an old technology does not find switching profitable. Excess inertia can arise here if the first potential adopters to consider the new technology are not prepared to give up the transient benefits from being compatible with the installed base of the old technology. They then adopt the old technology, swelling the ranks of the installed base and making the old technology even more attractive. In that case the new technology cannot get off the ground. This can happen even if the new technology would be much preferred by most new users if it became established. The failure of the market in this case is that the first potential users to consider the new technology confer a benefit on later adopters that they do not take into account in making their adoption decisions. Cooperative standard-setting will not be able to overcome this problem because, by assumption, early potential adopters highly value the benefits of compatibility with the installed base.

However, excess momentum can also occur when the new technology is adopted, but the harm imposed on users of the old technology, who are thereby stranded, exceeds the benefit to new adopters from the new technology. This result is important because it suggests that simple public policies aimed at encouraging the adoption of new technologies can exacerbate an existing bias in the market.[42]

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[41]Thus, although "bandwagons" may overcome the need to employ cooperative standard setting to achieve efficient adoptions, they may also promote inefficient ones. Moreover, in the latter case, cooperative standard-setting may not only fail to overcome this tendency but it may actually promote it.

[42]Rosenberg (1976) and Ireland and Stoneman (1984) also show that such policies can have the unexpected effect of slowing the adoption of new technology. An adopter of a new technology knows that these policies provide an incentive to new innovation, increasing the chance that the new technology will itself soon be obsolete. See David (1986c)

The second model examines what happens when adoption takes time. Here, all potential adopters of a new technology are users of an old one. The first adopter of the new technology will lose any compatibility benefits he currently enjoys until others also adopt the new technology. At the same time, any user who does not switch to the new technology may find himself temporarily stranded with the old technology if other users switch before he does. If the first of these effects is very strong, excess inertia may arise with no potential adopter willing "to take the plunge," with the result that all remain with the old technology. If the latter effect is very strong, excess momentum may arise, with each potential adopter rushing to be the first to adopt out of fear of being temporarily stranded.

In the above models, potential adopters choose between the *status quo* and a single new technology. Arthur (1985) shows that the "wrong" technology may be chosen even when a sequence of first-time potential adopters are choosing between two new technologies.[43] As in the Farrell and Saloner (1986b) model discussed above, early adopters are pivotal. If most favor one of the technologies and adopt it, it becomes relatively less expensive for later adopters who, in turn, may find it uneconomical to adopt the other technology. However, if the majority of later adopters would have preferred the other technology, society may have been better served by its adoption. In that case, the chance predisposition of early adopters to the socially inferior technology, and the fact that they serve their own, rather than society's, interests, results in the the less preferred technology being chosen as the standard.[44]

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and David and Stoneman (1985) for a discussion of these and other implications of public policy aimed at hastening technology adoption.

[43]In the simplest version of Arthur's model, the demand side externalities arise from "learning by using," where each time a potential adopter selects one of the technologies, the costs to later users of the same technology are reduced. However, the model can easily be extended to the case of compatibility. See David (1986a) for a discussion of this point.

[44]Cowan (1986) analyzes the same phenomenon from a different perspective. As in Arthur's model there is learning by using. In addition, however, potential adopters are unsure which technology is better. Each trial of a technology provides some information about its

b. Communication, Cooperation, and Contracts

Where an inefficient standard emerges, for example, where a new standard is adopted despite the great harm inflicted on the installed base, the failure of the market to select the "right" standard can be avoided if all potential adopters could somehow coordinate their activity and make appropriate side payments. If such contracts and side payments could overcome any inefficiencies, it is important to know why they will not naturally arise within a market setting.

Several possible reasons exist. The most important of these is that many of the agents whose adoption decisions are relevant are not active market participants at the time the new technology becomes available, but arrive much later. In principle, one could imagine a scheme in which a fund is provided by current users to provide subsidies to later adopters as they arrive. However, each current member of the installed base would have an incentive to free ride on the contributions of the others, or if a method of taxes and subsidies was used, to understate their true aversion to stranding.[45] Moreover, if, as in Arthur's model, there is uncertainty about the preferences of future adopters, even a central authority would often err in its choice of a standard.[46]

An additional difficulty arises if there is asymmetric information about adopters' preferences. Farrell and Saloner (1985) explore the implications of communication in their asymmetric information bandwagon model and find that communication is a mixed blessing. Where potential adopters are unanimous in their desire to adopt the new technology, communication facilitates coordination and eliminates excess inertia. However, if they have differing preferences, communication can actually make matters worse. A potential adopter who is only slightly averse to

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desirability. Thus, as in the above models, there is a connection between the welfare of late adopters and the decisions of early ones. Since early adopters ignore the value of the information they provide to late ones, from a social point of view there may be too little exploration of the value of alternative technologies.

[45]This free rider problem would arise, of course, even if the model were "timeless".

[46]David (1986b) calls such a central authority a "blind giant."

the adoption of the new technology will exaggerate his degree of aversion, making it even less likely that a bandwagon will get started. This suggests that there are circumstances in which inertia may actually be *increased* if there is an attempt to set voluntary standards through industry committees.[47]

c. The Development of Translator Devices or "Gateway" Technologies

In the above analyses, potential adopters face the choice between two inherently and unalterably incompatible technologies. In practice, however technical compatibility is not required for two components of a system to be able to communicate. Where components have not been designed to be compatible, devices, variously known as translators, adapters, converters, or gateways, can often be employed to permit them to interact.[48] Indeed, if translation were costless and technically perfect, standardization would be unnecessary.[49] However, translation is

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[47]Another portion of the literature addresses the trade-off between standardization and variety. Farrell and Saloner (1986a) show that when the degree of standardization is left to market forces, too little variety may be provided if the existence of an historically favored technology prevents an otherwise viable alternative from getting off the ground. Matutes and Regibeau (1986) address the case in which products are combined in "systems" and show that standardizing the product interface can *increase* the variety of systems by facilitating "mix-and-match" purchases. However, it can also lead to higher prices.

The compatibility of *components* may also have implications for technology adoption. Berg (1985) compares a regime in which there are two competing technologies with one in which there is only one technology. In the former, one of the technologies may eventually become the *de facto* standard. In that case, the adopters of the abandoned technology may find that compatible components are no longer provided. The realization of this possibility will tend to dampen the demand for both technologies, leading to slower technology adoption. Farrell and Gallini (1986) show that a monopolistic supplier of the primary good may encourage competition in the component market in order to mitigate this problem.

[48]See Braunstein and White (1985) for a brief discussion of translators as a substitute for standards.

[49]By technically perfect we mean that messages sent in either direction and then returned are identical to those that were orginally transmitted.

often costly and something is often "lost" in translation. Nonetheless, there is a thriving business in the sale of devices that permit communication in the absence of compatiblity.[50]

The existence of translators has a number of implications for standardization, most of which have not been addressed in the theoretical literature:

First, in some circumstances, the use of translators may be more efficient than the development of standards. Standard-setting is costly, and if only a few users wishes to combine incompatible components it may be less costly for them to employ translators than to attempt to achieve standardization. Moreover, if the principal uses of the incompatible components are to serve users with different needs, important benefits may be lost if standardization is required.

Second, translators are likely to be important during the period in which a number of incompatible technologies are vying to become the industry standard and consumers wish to have access to a larger "network" than any single technology can provide. The existence of translators permits the deferral of the choice of a standard until more information about the various technologies becomes available. This does not mean, of course, that either the market or standard-setting bodies will necessarily select the efficient standard after the period of experimentation, but better choices may be possible if there are more data about the competing technologies.

Third, the existence of translators may promote the development of specialized uses for particular technologies and thus narrow the range of uses of each. David and Bunn (1986) argue, for example, that the development of the rotary converter for "translating" AC to DC electrical current delayed the development of high voltage DC transmission.

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[50]Some examples of translation devices are: (1) Word For Word which is a "software document converter that converts files and documents from one PC-compatible word processing system to another." (Advertisement in *Byte*, 1986 Extra Edition, p. 229); (2) a series of products offered by Flagstaff Engineering that "can connect your incompatible computer systems using diskette, tape, communications, or printed media." (Advertisement in *Byte*, September 1986, p. 320); and (3) PC<>488 which "allows your IBM PC/XT/AT or compatible to control IEEE-488 instruments." (Advertisement in *Byte*, November 1986, p. 155).

Finally, the presence of translators may reduce the incentives to achieve standardization. So long as incompatible components can be combined into a system, consumers are likely to be less willing to demand that manufacturers standardize and manufacturers are likely to be less willing to incur the costs of doing so.

Nonetheless, it is possible to overstate the extent to which translators can and will substitute for standards. There are likely to be cases in which translation is technically inefficient and/or in which the costs of achieving translation are high.[51] A number of large communications users have emphasized to us the value to them of having standardized communications networks and have argued strongly that, for them, translators are a poor substitute. They are thus likely to be an important force in promoting standardization.

5. STANDARDS AND COMPETITION

For the most part, the models discussed in the previous section have in common that the prices for the different technologies that the potential adopters face are not explicitly considered. This is consistent with markets in which the various technologies are competitively supplied so that adopters face competitive prices. This feature of the models is important since if, instead, the technologies were offered by firms with some market power, the firms might have an incentive to behave strategically. In this section we examine strategic actions of three kinds: First, we analyze the effect of strategic pricing on the market's choice of technology. Second, we examine the effect of truthful advance announcements by firms that they propose to introduce a new product. Finally, we study the contention that leading or dominant firms, or firms with control over "bottleneck facilities," might use their positions to choose or change standards in order to disadvantage their rivals.[52]

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[51]Also, Katz and Shapiro (1985) have shown that firms providing incompatible technologies will generally not have the correct incentives to provide converters.

[52]See Adams and Brock (1982) for an example of this view.

a. Strategic Pricing and Product Preannouncements

Katz and Shapiro (1986a) examine the implications of strategic pricing in a two period model when there is competition between two technologies. The most interesting case they consider is one in which each technology is offered by a single firm and one technology has lower costs in the second period but higher costs in the first period.[53] They find that the sponsor of the technology that will be cheaper in the future has a strategic advantage. This is a somewhat surprising result and its flavor is exactly the reverse of that in the models of the previous section, where there is a tendency for adopters to choose the technology that is more attractive at the time that they adopt.

The intuition behind their result is the following: Where each technology is provided by a single sponsor, that firm has an incentive to price very low early on, even below its cost, to achieve a large installed base and become the industry standard. However, potential adopters know that later on ("in the second period") the firm will no longer have an incentive to use "promotional" pricing and will charge a higher price. Potential adopters therefore expect the firm that will have the lower future costs also to have the lower future prices. If both firms charge the same first period price, potential adopters will therefore prefer the technology that will have lower future costs. Put differently, the firm that has higher first period costs can overcome that disadvantage by promotional pricing. However, the firm that has higher second period costs cannot do the same since consumers will rationally expect the firm to exploit its dominant position at that stage.

Strategic behavior results in lower prices for consumers. It does not, however, guarantee that the technology with the lower overall cost is adopted. At the same time, however, a ban on promotional pricing might prevent the adoption of the technology with the lower cost.

[53]They also study the case where both technologies are competitively supplied. Their results in that case are similar to those of Farrell and Saloner (1986b) discussed in the previous section.

Similar problems arise in the the model developed by Farrell and Saloner (1986b). Recall that in that model there is an installed base of users of an old technology when a new technology becomes available. As a polar case, they consider what happens when the new technology is supplied by a competitive industry, while the old technology is supplied by a monopolist. They show that in some circumstances the monopolist will be able to prevent the new technology from being adopted by offering a discount to potential adopters.[54] This discount need not be offered to all adopters. Instead, there may be some critical installed base at which the old technology will become invulnerable because the compatibility benefits from joining the installed base are so large. Once that point is reached, the monopolist need no longer offer a special inducement. There is thus a window of opportunity for the new technology that the monopolist may be able to close through strategic pricing. Moreover, this entry prevention tactic may be successful even where the new technology would have been superior from a social point of view.[55]

The Farrell and Saloner (1986b) model can also be used to demonstrate that a simple announcement that a product will be available in the future (a "product preannouncement") can make the difference between the adoption and nonadoption of a technology. To see this, suppose that the *old* technology is competitively supplied, but that the new technology is supplied by a monopolist. By the time the monopolist is ready to introduce its product the installed base on the old technology may make entry impossible. By preannouncing the introduction of a new product, the monopolist may be able to induce some potential adopters to wait for its arrival. If that occurs, the new product will begin with an installed base of its own, making it the more attractive technology to later adopters. As in the case of strategic pricing, the

[54]The same advantage exists when a monopolist is the supplier of a new technology that is incompatible with one offered by a competitive industry.

[55]Katz and Shapiro (1986b) find the same result in their two-period model.

preannouncement can result in the adoption of the socially less-preferred technology, in this case because it leads to the stranding of users of the old technology.

b. Standards and "Bottleneck" Facilities

For the most part, the theory of non-cooperative standard-setting discussed thus far focuses on the market for a "primary" good, e.g., computers, in which compatibility is sought or avoided because of its effect on demand in the primary market. In those analyses, the effect of compatibility, pricing, and preannouncement decisions in the primary market on the market for the secondary good is not analyzed in detail, because it is implicitly assumed that producers of the primary good do not participate in that market.

The situation in the telecommunications market is somewhat different. Here, one set of firms, the local telephone companies, is assumed to control the market for basic telephone transmission capacity, the primary market.[56] At the same time, these firms are, or would like to be, participants in the secondary markets for customer premises equipment (CPE) and enhanced telecommunications services. The questions that face regulators are (i) whether control of the primary market can be extended, through the use of standards or in other ways, to the secondary markets and (ii) whether the local telephone companies will have the incentive to attempt to "leverage" their market power in this manner.[57]

[56]Whether this presumption is true is not addressed in this paper, although the conclusions would be affected if there were effective competition in the transmission market. Similar issues arise in countries where a single entity controls the entire telecommunications system and competes with outside suppliers. This explains the large role given to the achievement of common standards by the Commission of the European Communities (1987). The Commission is concerned with "the promotion of Europe-wide open standards, in order to give equal opportunity to all market participants." (p. 5).

[57]This is akin to the issues raised in the various antitrust cases involving IBM, where it was alleged, among other things, that IBM manipulated its interconnection standards to extend its putative monopoly in the market for mainframe computers to the market for peripheral equipment. This paper is not the occasion to revisit the issues raised in these cases. We raise the examples of the IBM cases only because they present analogies to policy questions in the telephone industry. For a vigorous defense of IBM's actions see Fisher, McGowan, and Greenwood (1983).

The use of standards to increase profits in either the "system" market or in the market for a complementary good is analyzed in detail in Ordover and Willig (1981).[58] They consider a firm that is either the only supplier of one component of the system, the "primary" component, or that has a cost advantage in producing that component.[59] Other components of the system can be produced by rivals at the same cost.[60]

It is well known that, if the firm has a monopoly over one component, it will often be able to obtain maximum profit without regard to the presence of rivals in the competitive market *so long as there are no constraints on the price, or prices, that it can charge*. Consider the simplest case in which all consumers place the same value on a system and all firms have the same costs in producing all components but the "primary" one. Suppose that the cost of producing the primary component is 10, the cost of producing a secondary component by any firm is 5, and the value that each consumer places on a system, or its constituent components, is 25. If there are no constraints on the prices that the firm can charge, it can set the price of a system at 25, the price of the primary component at 20=[25-5], and the price of the

[58]See also Ordover, Sykes, and Willig (1985). Ordover and Willig actually describe a large number of ways in which firms might attempt to exercise such leverage. These include refusing to sell the primary good to a rival; selling only complete systems and not their components; selling both systems and components but setting high prices for components if purchased separately; "underpricing" components that compete with those sold by rivals; and "overpricing" components that are needed by rivals to provide complete systems. Thus, standards are only one of a number of tools that a firm can use strategically to disadvantage its rivals and to increase its profits. It should also be observed that these are all variants of the "raising rivals' costs" strategies analyzed in detail in Krattenmaker and Salop (1986).

[59]It should be clear that the component is called primary not because it is any more necessary than any other component but because of the advantage that the firm has in producing it.

[60]The ability to use standards in such an anticompetitive manner is severely limited if efficient low-cost translators are available. For example, a firm that seeks a competitive advantage by designing interfaces that cannot directly accomodate the products of its rivals will find the strategy unsuccessful if users can easily connect incompatible devices through the use of translators.

secondary component at 5. The firm obtains a profit of 10=[25-10-5] on each system that it sells directly to consumers. However, even where a consumer purchases only the primary component from the firm, it still obtains a profit of 10=[20-10]. The firm is, thus, indifferent as to whether consumers purchase the entire system or only the primary component from it since its profits are the same in either case. If rival firms can produce the secondary component more efficiently, say at a cost of 4, the profits of the firm are actually increased if it leaves the market for the secondary component to them. It can charge a price of 21=[25-4] for the primary component and obtain a profit of 11=[21-10], which is larger than the profit of 10 it obtains from selling an entire system.

However, it may pay to eliminate a rival if there are limits on the prices that can be charged for the primary component. Thus, in the previous example, if the firm can charge at most 12 for the primary component, say, because of regulation, then so long as it can charge any price above its cost on the secondary component it will wish to eliminate its rivals and dominate the secondary market, as well. If it can, for example, charge 6 for the secondary component, its profits are 3=[12+6-10-5] if it can sell both components, or an entire system, while it can earn only 2=[12-10] if it is limited to selling only the primary component. Indeed, if the firm can charge 13 or more for the secondary component it can earn the entire monopoly profit even with the restriction on the price it can charge for the primary component. If, however, there are rivals in the provision of the secondary component, and if the firm must make the primary component available at a price of 12, its profits are limited to 2=[12+5-10-5]. This occurs because consumers will buy the secondary component from the firm's rivals if it attempts to charge a price in excess of 5. This is what gives the firm an incentive to eliminate its rivals. One way in which it can do so is to make its primary component incompatible with the secondary component manufactured by its rivals.

The firm might also wish to eliminate its rivals if different consumers place different values on systems and these differences are proportional to their use of the secondary component. Suppose, for

example, that there are two consumers, one that places a value of 25 on a system consisting of one of each component and the other that places a value of 40 on a system consisting of one primary component and two secondary components. The firm's costs are the same as in the previous example.

If there is no competition in the secondary market, the firm can offer the primary component at a price of 10 and each of the secondary components at a price of 15, and capture the entire consumers' surplus. Its profits in this case are 45=[40+25-10-10]. However, if there are rival suppliers of the secondary component who can produce at a cost of 5, so that the firm must obtain its profits entirely on the primary component, it will sell the primary components for 20 and earn profits of only 20=[20+20-10-10].[61] Eliminating a rival is desirable because it permits price discrimination that would not otherwise be possible.[62] Once again, a possible strategy for eliminating rivals is to design the primary component so that it is incompatible with the components produced by rivals.

The two elements necessary for the types of strategies analyzed by Ordover and Willig to be employed both appear to be present in the telephone industry. First, there are regulatory constraints on the prices that can be charged for the primary product, access to the transmission network. These constraints take the form of limits both on the overall rate of return that the firm can earn and on the prices of individual services. Second, the primary product may be a "bottleneck" or "essential facility" that is needed if the suppliers of enhanced services or CPE are to be able to sell their wares.[63]

[61]The firm's profits are the same if it sells only one primary component at 30. The analysis assumes that the firm cannot offer only complete systems at discriminatory prices.

[62]This is analogous to the argument that firms will vertically integrate forward in order to permit them to practice price discrimination. See Gould (1977).

[63]To the extent that suppliers of enhanced services or CPE can "bypass" the local transmission facilities of a telephone company, the ability of the telephone company to use standards anticompetitively is reduced.

At the same time, one of the assumptions in the examples presented by Ordover and Willig must be brought into question. In their examples, the firm that controls the primary market does not, as a result, have a cost advantage in producing the secondary goods. In such cases, no loss in efficiency results from a ban on the participation of suppliers of the primary good in the secondary markets. Similarly, there is no loss from requiring them to participate in these markets through separate subsidiaries, so that instances of anticompetitive behavior can be more easily detected.

In addressing the effects of the limitations placed on AT&T by its Computer II decision, however, the FCC noted that "the inability to realize...scope economies was one cost of structural separation for AT&T's provision of CPE; and we believe the elimination of such costs could well result in efficiencies for AT&T's provision of enhanced services, to the extent that such services could be integrated into or colocated with AT&T's basic network facilities."[64] And, in examining the effects of similar restraints on the BOCs, the Commission observed "that structural separation imposes direct costs on the BOCs from the duplication of facilities and personnel, the limitations on joint marketing, and the inabilty to take advantage of scope economies similar to those we noted for AT&T."[65] If the economies of scope noted by the FCC are important, a blanket ban on BOC participation in the CPE and enhanced services markets, although it might prevent anticompetitive behavior, might also prevent efficient supply.[66]

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[64]Federal Communications Commission, Report and Order In the Matter of Amendment of Sections 64.702 of the Commission's Rules and Regulations (Third Computer Inquiry); and Policy and Rules Concerning Rates for Competitive Common Carrier Services and Facilities Authorizations Thereof; and Communications Protocols under Section 64.702 of the Commission's Rules and Regulations, CC Docket No. 85-229, Adopted May 15, 1986, released June 16, 1986, para. 80.

[65]Id., para. 90.

[66]See Phillips (1986) for a forceful statement of the proposition that substantial efficiency losses will result if the BOCs are confined to providing basic service.

We conclude that the conditions are present under which standards might be used to disadvantage the competitors of those who control access to the telecommunications transmission system. To prevent these and other forms of anticompetitive behavior, the FCC and the courts have either prohibited the telephone companies from providing certain services or have required that these services be provided through fully separated subsidiaries. However, if telephone companies have lower costs than these competitors, either a blanket prohibition or a separate subsidiary requirement might be economically inefficient. As a result, the FCC has begun to pursue an alternative approach under which the restrictions on the telephone companies are eliminated and, at the same time, a regulatory framework to make the anticompetitive use of standards more difficult is established.

6. TELECOMMUNICATIONS STANDARDS, TELEPHONE REGULATION, AND THE FCC

Until the 1960s, standardization was not a major telecommunications policy issue since there were no competing providers of equipment, or of communications services, who might be adversely affected by the standards that were chosen by AT&T.[67] However, beginning with the FCC decision in the Carterfone case,[68] which introduced competition into the supply of equipment to telephone customers, standards have become an increasingly important policy concern. In adopting its equipment registration program, in which it sought to eliminate technical barriers to the entry of independent equipment suppliers, the Commission required, with one minor exception, that "all terminal equipment be connected to the telephone network through standard plugs and jacks."[69] And, in its Computer II decision, [70] in which it sought to promote

[67] Of course, consumer welfare could depend on the choices that were made.

[68] *Use of the Carterfone Device*, 13 FCC 2d 420, reconsideration denied, 14 FCC 2d 571 (1968).

[69] 56 FCC 2d 593 (1975), p. 611.

[70] *Second Computer Inquiry*, 77 FCC 2d 384 (1980).

competition in the market for equipment and enhanced services, the FCC required that technical information that independent suppliers might need to compete had to be provided to them on the same terms as to the subsidiaries of the telephone companies. In this regard, the Commission singled out "information relating to network design and technical standards, including interface specifications [and] information affecting changes which are being contemplated to the telecommunications network that would affect either intercarrier connection or the manner in which CPE is connected to the interstate network." (Para. 246)[71]

The decisions by the FCC to require standardized interconnection for terminal equipment and that technical information be provided to independent suppliers were part of an effort designed to make it possible for independent equipment vendors to compete effectively in the supply of this equipment. Although the Commission did not itself participate in the process of establishing interconnection standards, leaving their determination to the industry, its policy has been enormously successful, at least as judged by the wide variety of equipment that is now available and by the sharp declines in the market shares of the telephone companies.[72]

Under the Modified Final Judgment that settled the government's antitrust suit against AT&T,[73] the Bell operating companies are

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[71]Although the requirement that competitors be provided with information limited the ability of AT&T to use standards to disadvantage its rivals, AT&T might still prefer different standards from those desired by their rivals.

[72]In the early 1980's, AT&T's share of the Customer Premises Equipment market had declined to somewhat over 60 percent (U.S. House of Representatives, 1981) and by 1986 its share of Total Lines Shipped had fallen further to about 36 percent for handsets, 25 percent for key systems, and 20 percent for PBXs (Huber, 1987). In the United Kingdom where entry of independent suppliers of terminal equipment did not begin until much later than in the U.S., and where a somewhat different equipment registration program exists, non-British Telecom suppliers have captured half of the addition of the installed base of telephones since 1980 and about 10 percent of the key system market (Solomon, 1986).

[73]United States v. Western Elec. Co. (American Tel. and Tel. Co.), 552 F. Supp 131 (D.D.C. 1982).

"prohibited from discriminating between AT&T and other companies in their procurement actitivities, the establishment of technical standards, the dissemination of technical information,...and their network planning."[74] Moreover, the MFJ "...requires AT&T to provide [the] Operating Companies with, *inter alia*, sufficient technical information to permit them to perform their exchange telecommunications and exchange access functions....The Operating Companies, in turn, are prohibited from discriminating in the 'establishment and dissemination of technical information and procurement and interconnection standards.'"[75]

Finally, in its Computer III decision,[76] the Commission indicated that it would waive its requirement that the operating companies provide enhanced services only through separate subsidiaries if competitors were provided with Comparably Efficient Interconnection (CEI) and an Open Network Architecture (ONA) plan acceptable to the Commission had been offered. The requirement of CEI is intended to provide competing suppliers with access to the telephone transmission system on the same basis as the subsidiaries of the telephone company that are providing the same services. ONA means that the components of the telephone system are to be made available to competing suppliers on an unbundled basis so that they can be combined with the services of these suppliers in any manner that is desired. The nature and identities of these components--the Basic Service Elements--in ONA are likely to be contentious issues since they will affect the potential for competition. Competing suppliers will undoubtedly wish to have highly disaggregated components with which they can interconnect easily. The telephone companies are likely to argue for a higher level of aggregation.

Both the interfaces with the basic service elements and the number and nature of these elements are standards issues. The first involves an obvious standards concern since the design of these interfaces will determine whether a competing supplier can employ a particular element

[74] Id., p. 142.
[75] Id., p. 177.
[76] 60 RR 2d 603 (1986).

in offering his services. Less obvious is why the second is a standards issue. If components can be obtained only on a bundled basis, the interface between them is completely inaccessible to the competing supplier. But the economic effect of an inaccessible interface is exactly the same as if it were accessible but incompatible with the supplier's equipment. Providing components only on a bundled basis is the limiting case of incompatibility.

Two broad lesssons can be drawn from this history. First, the range of services that independent suppliers can offer to telecommunications customers has increased markedly over the last three decades as the restrictions previously imposed by AT&T have been eliminated by regulation. Indeed, the initial effect of many regulatory interventions was either to deny AT&T, and later the BOCs, the ability to provide certain services or to restrict the way in which the services could be offered.

Second, the elimination of the restrictions placed on the provision of services by the telephone companies is being conditioned on the imposition of behavioral constraints designed to facilitate competition from independent suppliers. These constraints include requirements that information about network design changes be promptly provided to competing vendors, that these vendors be provided with interconnection to the telephone system that is "comparable" to that provided when a telephone company itself offers a service, and that the components of the network be available on an "unbundled" basis so that customers can acquire from the telephone companies only those portions of network services that they desire.

7. THE DETERMINATION OF TELECOMMUNICATIONS STANDARDS

In Sections 2 and 3 of this paper, we examined why suppliers may seek to standardize their services to increase the value of their offerings to consumers and the difficulties involved in achieving such standardization. In Sections 5 and 6, we discussed how standards can be used as a competitive weapon. This section examines two cases of standard setting in telecommunications, ISDN and Open Network Architecture, to illustrate both phenomena.

a. ISDN Standardization

A worldwide effort, involving literally thousands of individuals, is currently underway to develop standards for ISDN.[77] This effort is intended to define the architecture of ISDN and to promote common ISDN standards in different countries. The countries involved in attempting to set ISDN standards through the CCITT are interested in achieving compatibility among their various national telecommunications networks to achieve the demand side economies of scale discussed earlier. As we have already seen, however, even where compatibility is highly valued, it may not be easily achieved.

The principal reasons are that, even if all countries value compatibility, they may not agree on what the single standard should be and that some countries may prefer a degree of *incompatibility* to shelter their domestic telecommunications suppliers from foreign competition. As a result, achieving agreement on common standards is likely to be a slow process and differences among national systems may persist. Indeed, there is some danger than the slowness of the process may encourage the development of incompatbile systems by those unwilling to wait for international consensus.

In attempting to achieve standardization among national ISDNs, the CCITT has not confined its activities to the specification of a single dimension of each interface through which information can move. Instead, it has pursued a strategy of attempting to achieve compatability at a variety of "layers," ranging from the physical interconnections that will be permitted to the forms in which data will be recognized. [78] Because communication must be effected at all layers at each interface, the specification of standards is quite complex.

Moreover, not only are the various interface specifications being specified but so is the architecture of the ISDN. This means that the standards will encompass where the interfaces will be and whether they

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[77] Rutkowski (1985) contains an extensive description of this process.

[78] These layers are patterned, to a substantial degree, on those in the Open Systems Interconnection (OSI) Reference Model.

will be accessible by users or independent suppliers. Clearly, the more alike are the various national systems the simpler and less costly will be the required interfaces between them. But the fact that the architecture of ISDN will be specified by CCITT may create problems in those countries, such as the United States, where there are a large number of competing suppliers of telecommunications services.[79]

The concern is that the design of ISDN, in particular restrictions on user access, can be used to limit the competition faced by the operators of the transmission network. As a result, there may be significant conflicts between users and suppliers. Rutkowski (1985, p. 46) puts the point succinctly: "...users generally have an interest in maximizing their service options, while providers (particularly telephone network providers) have an interest in limiting those options to maximize their operating efficiencies and minimize losses to competitive providers."

From the perspective of establishing standards, the most significant aspect of the development of ISDN is the increase in the number of interfaces at which access to the telecommunication network can occur and the ways in which such access can take place.[80] Where before the Carterfone decision "access" was available only at an AT&T-supplied terminal, subscribers, or providers of enhanced services, can now obtain access to the system at a number of points using a number of different types of equipment. ISDN is likely to further increase this number. However, a significant degree of standardization of interfaces and terminals must be accomplished for this to occur.

Consider a message that must "access," i.e., pass through, a particular node in the telecommunications network if it is to reach its intended destination. To obtain access, a number of components are required to establish a "path." The first such component is the

[79] Although not as far along as in the U.S., this development is also occurring in the United Kingdom and Japan.

[80] The introduction of Open Network Architecture in the United States will have a similar effect. A recent article argues that the effect of ONA is likely to be an increase in the number of interfaces by "an order of magnitude." See Editorial, "Part 68 Is Not Compatible with ONA," 21 *Telecommunications*, North American Edition, January 1987, p. 8.

subscriber's terminal equipment. This can be either a device with a standard ISDN interface, e.g., a digital telephone, or one that requires an adapter to access a digital network. Second, there is network equipment required to perform switching and concentration functions. An example of such a device is a digital exchange. The third type of component is network termination equipment that lies between the transmission system and the subscriber's premises. It is the connection between the subscriber's premises and the local telephone loop. Certain types of equipment permit the second and third components to be combined. Finally, there is the link between the local loop and the network itself.

The subscriber can employ these components in various ways and, depending on the regulatory regime, may choose to obtain many or few of them from the telephone company. In the United States, for example, a subscriber might employ a terminal requiring an adapter, as well as the adapter and both types of termination equipment from the telephone company.[81] Alternatively, he might obtain the adapter from an independent vendor and the termination equipment from the telephone company. Or, he might also purchase the "switch" from an independent vendor and only the last link from the telephone company. Or he may acquire all of the components from independent vendors. Similarly, a subscriber may employ a terminal that does not require an adapter but may purchase any or all of the remaining components from independent vendors.[82]

The ISDN model currently under consideration does not contemplate an interface at which a subscriber, or an independent service provider, can obtain access to the system without employing the telephone company's local loop.[83] This is consistent with the views of most Post,

[81]Conceivably he might purchase the various components from different parts of the company.

[82]Of course, this wide range of options is available only where competitive suppliers exist. In many countries, all components must be acquired from the telephone company.

[83]In the language of CCITT, this is not a "reference point." See Rutkowski (1985, pp. 145-146.)

Telephone, and Telegraph Administrations and, probably, with those of the BOCs, which would like to require use of this loop. It is not, however, consistent with the views of independent suppliers who wish to maximize the number of points at which they can obtain access so that they can employ as much or as little of telephone company-supplied services as they desire. Thus, even if there were no controversy about the designs of the interfaces that were actually offered, there might still be a dispute over how many were offered and where they were located.[84]

United States policy is likely to vary from international ISDN standards if the latter do not permit access to the network without use of the local loop. For example, U.S. vendors can expect to obtain access through the telephone company network and, indeed, there have even been discussions of whether Comparably Efficient Interconnection requires that the equipment of these vendors be located at telephone company central offices.[85] One continuing policy concern is thus likely to be which interfaces are available to independent suppliers and on what terms.

One way to assuage this concern is for the telephone companies to provide, as they are currently required to do, unbundled private line service, i.e., pure transmission capacity, along with ISDN.[86] Thus, ISDN would not completely replace the existing telecommunications system, but some elements of the old system would remain. As a result, independent suppliers would have substantial freedom to construct their own networks using telephone company-provided private lines and other components of their own choosing. These systems would employ none of the "intelligence" in the telephone company's ISDN but would be able to

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[84]Note that denying access is equivalent to providing an interface that is totally incompatible with the equipment of one's rivals.

[85]Note that denying access to independent vendors at the central office may be equivalent to the strategy, discussed by Ordover and Willig (1981), of not making certain components of a system available to rivals, depending on the costs of the alternatives.

[86]This is apparently contemplated by the CCITT but, in any event, it is likely to be an element of United States telecommunications policy.

provide many, or all, of the same services. As a result, even if all of the elements of an ISDN were not available on an unbundled basis, enough other resources could be available to make feasible the provision of competitive offerings. This would also provide protection to competing vendors against the possible manipulation of the design of interfaces for strategic purposes. Thus, although a requirement that private line service continue to be provided does not appear to be a standards issue, it may be a partial substitute for complete agreement on standards.[87]

Still another way to prevent carriers from using standards in an anticompetitive manner is to limit their ability to provide certain types of services, or to limit the way in which they may do so.[88] However, as we have already noted, drawing the line between the provision of basic (transmission) and other services is becoming increasingly difficult. It will become more difficult with the introduction of ISDN, where the network itself will contain a substantial amount of intelligence. Moreover, economies may be lost if such restrictions are imposed. In any event, existing restrictions are being relaxed, so that competition between exchange carriers and independent service suppliers is likely to increase. The result is that these suppliers will remain concerned about where they can obtain access, and what the nature and terms of that access will be. Regardless of how ISDN standardization issues are resolved by the CCITT, these issues are unlikely to go away any time soon.

b. Open Network Architectures

The Bell Operating Companies are currently involved in developing Open Network Architecture plans which, if accepted by the FCC, will relieve the companies from some of the restrictions they face in

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[87]Alternatively, it can be thought of as providing an alternative interface. It should also be noted here that the pricing of private lines as well as of competing telephone company offerings will affect the nature of competition. As Ordover and Willig (1981) note, "underpricing" components that compete with those sold by rivals and "overpricing" components that are needed by rivals may be part of a competitive strategy. Thus, even if private lines are available, they will not be an attractive alternative to ISDN if they are very costly.

[88]This is, of course, the approach taken in *Computer II* and in the *Modified Final Judgment*.

offering enhanced telecommunications services. The FCC will require that ONA plans offer users the opportunity to purchase unbundled Basic Service Elements (BSEs) so that users can configure their own telecommunications networks using as much or as little of the BOC networks as they desire. Two standards issues are raised by these develoments. First, what will the Basic Service Elements be? Second, will the BOCs offer standardized ONA plans?

The choice of BSEs is a standards issue because offering to parts of the network only on a bundled basis is economically equivalent to making it impossible for users to connnect to the interface between them. As in the case of ISDN, network users will desire that the elements of the network be offered in small "bundles" so that they can purchase from the BOCs only the portions that they want. Other elements will be purchased from other vendors or provided directly by the user, which may itself be an independent service provider. On the other hand, the BOCs will presumably want to offer more aggregated bundles so as to limit the choices of users. Alternatively, the BOCs can make many small elements available but, by failing to standardize their interfaces, may force users to buy more elements from the BOCs than they would desire. For these reasons, considerable controversy is likely to make the announcement of the ONA plans.

Whatever the ONA plans contain, there will also be the issue of whether they are the same for all BOCs. Although some large telecommunications users have expressed concern that lack of uniformity will increase their costs[89], there is presently no formal mechanism to coordinate the standards that will be used in the various regions of the United States.[90]

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[89] Betts (1986) describes a large user who "is worried that the lack of standard protocols will increase cost for equipment, staff expertise and software and complicate operating procedures as well as hamper the diagnosis and resolution of network problems" and quotes the counsel for the International Communications Association, a group of large users, that "We have an overall concern that we may end up with seven separate, incompatible, ONA plans."

[90] However, see the discussion of the Information Industry Liaison Committee below.

The economic theory of standards suggests three possible reasons why standardized ONA plans may not emerge: (1) large differences in preferences among the BOCs; (2) difficulties in coordination among the BOCs even if preferences are similar; and (3) the desire of some or all BOCs to achieve a competitive advantage through the adoption of different ONA plans.[91] If the BOC do not adopt uniform plans, the outcome may be: (a) the absence of a national standard, with slow development of new technologies resulting because users who operate in different regions find the costs of employing incompatible technologies too costly; (b) the simultaneous use of incompatible technologies in different regions despite the higher costs and lower benefits for users; or (c) the emergence of one technology as the standard through a "bandwagon" in which those BOCs using other technologies are forced to switch to the standard.

A uniform national standard may fail to develop rapidly if users, uncertain about whether a national standard will emerge and what that standard will be, adopt a "wait and see" posture. If the fear of being stranded with the wrong technology results in such behavior by a large number of users, "excess inertia" may result.[92] Excess inertia is especially likely if the BOCs have different preferences, but it can also occur if such differences do not exist. A coordinated standard-setting process might overcome this inertia.

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[91]A particular technology may be favored because it reduces the competition that a BOC faces from suppliers of equipment that compete with equipment offered by the BOC, or because it reduces the ability of other suppliers to offer equipment that provides services that could otherwise be offered through the network. The stated goal of the proposed European policy to achieve common telecommunications standards among countries (Commission of the European Communities, 1987) is to promote competition.

[92]Besen and Johnson (1986) conjecture that the absence of an AM stereo standard may be responsible for the slow rate of diffusion of that technology by radio stations and listeners. Inertia can also result if the benefits to users are reduced because incompatibility raises their costs.

A second possibility is the rapid adoption of incompatible technologies in different regions. This is likely if there are many customers whose communications are confined to a single region, so that incompatibility is unimportant to them, and/or if the benefits of using the new technologies exceed translator costs for users who communicate between regions. Note that, although the new technologies develop rapidly in this case, the cost of incompatibility to users -- in terms of translator costs or services not used because their benefits are less than the cost of translation -- may still be substantial and the outcome may be less efficient than if there were a common standard.

Third, one technology may emerge as the national standard. This can occur if a bandwagon that is started by early adopters produces changes in the offerings of those BOCs using other technologies. Once again, however, it is important to observe that the winning technology is not necessarily the one that is most economically efficient.

Finally, of course, the BOCs may adopt standardized ONA plans. As we noted in Section 2, three conditions seem especially important for this to occur. First, there are no important differences in the preferences of the various BOCs, which may exist here as long as none of the companies has made significant investments in a particular technology. Second, the growth of the market is highly dependent on the existence of a common standard because users place a great value on compatibility. Finally, the competitive advantages from incompatibility are small. If these conditions are met, standards may result through agreements among the BOCs. Recently, the Exchange Carriers Standards Association announced formation of the Information Industry Liaison Committee to "act as an ongoing national forum for the discussion and voluntary resolution of ONA issues."[93] Although the Committee is not a formal standard-setting body, its presence may still promote agreement on common standards.

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[93] "ECSA Sponsoring Information Industry Liason Committee on 'Open Network Architectures," 53 *Telecommunications Reports*, October 19, 1987, p. 15.

We do not mean to suggest that absence of a formal mechanism to achieve national uniformity will necessarily produce inefficient outcomes, or that the existence of such a mechanism will always overcome these inefficiencies. However, the main lesson of the theory discussed above is that there is nc guarantee that uncoordinated standard setting by the BOCs will achieve the efficient outcome and that there are many instances in which it will not. Moreover, it may be difficult to tell even after the fact whether the outcome is an efficient one. The emergence of a common standard and rapid diffusion are still consistent with the choice of the "wrong" technology.

8. CONCLUSION

Two basic lessons can be drawn from the economic theory of standard-setting. The first is that, even where everyone benefits from standardization, there is no guarantee that standardization will be achieved or, if it is, that the "right" standard will be chosen. The second is that standards may be used as tools of competitive strategy, with firms either seeking incompatibility or promoting their preferred technology as the standard to gain an advantage over their rivals. Moreover, both problems are present whether *de facto* standardization occurs through the market or voluntary standards are chosen cooperatively.

Not surprisingly, both lessons can be applied in telecommunications. The fragmentation of the industry, among regions in the U.S., internationally, or among user groups, may create coordination problems. The central role played by telecommunications carriers may create competitive ones. The examples of ISDN and ONA are only two instances of the growing importance of standards issues in this industry.

Much may be learned about the best way to set standards by observing the performances of the differing approaches to telecommunications standardization being pursued in the United States and Western Europe. In the U.S., standardization dictated by AT&T has been replaced by a system in which individual participants have

substantial autonomy and voluntary standard-setting has taken on increasing importance. In Europe, by contrast, a system in which individual countries have had substantial freedom to establish their own standards appears to be evolving into one in which countries forego some independence to obtain the benefits of more rapid technical change.

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